Determination of Toxic Heavy Metals of a Selected Dumpsite (Asunle Dumpsite), Ibadan, Oyo State, Nigeria

[1]T. E. AROYEUN, [2]B. B. OPALADE, [3]O. S. FATOKI

[1]+2348034365900/Tobility04@gmail.com,
[2]+2348161215957/Opaladebayonle8@gmail.com,
[3]+2348109667789/fatoki.olalekan@lcu.edu.ng

[1,2,3]Lead City University, Ibadan

Abstract

Levels of toxic heavy metals (Pb, As, Cd, Ni, Cr, and Hg) were determined in surface soils from the Asunle dumpsite (Ibadan, Nigeria), adjacent receptor areas, and a background control site using Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES). Concentrations for all metals were in the ppb (µg/kg) range and **below established residential soil limits.** However, a consistent gradient was observed: **receptor samples concentrations greater than dumpsite sample concentrations greater than control sample concentrations,** indicating outward migration of contaminants from the waste body. Indices of contamination (e.g., contamination factor, ecological risk factor, and geo-accumulation index) corroborated anthropogenic enrichment, with receptor soils showing the strongest signals—particularly for Pb, Cd, and Cr—despite absolute concentrations remaining low. Site activities such as informal scavenging and dismantling of materials likely contribute to localized hotspots and redistribution. Although current levels do not exceed guideline thresholds, the pattern of enrichment at receptors highlights the potential for progressive accumulation and associated ecological and health risks. **Routine monitoring**, improved leachate control, and targeted remediation of receptor soils are recommended to prevent long-term deterioration of soil quality and to protect nearby communities and ecosystems.

Keywords: Toxic Heavy Metals, Soil, Dumpsite, Ibadan, ICP-OES

Introduction

Toxic heavy metals—including lead (Pb), arsenic (As), cadmium (Cd), nickel (Ni), chromium (Cr), and mercury (Hg)—are environmentally persistent, non-biodegradable elements that can accumulate in soils and biomagnify through food webs, thereby posing chronic ecological and public-health risks (Alloway, 2013; Kabata-Pendias, 2011). Even at low concentrations, several of these metals have no known physiological benefit to humans and are associated with adverse health outcomes; notably, Pb and Cd are well-recognized for their toxicity at environmental exposure levels (WHO, 2023; ATSDR, 2022). Children and pregnant women are disproportionately vulnerable to Pb, for example, with no safe blood lead level identified and cognitive, developmental, and cardiovascular effects observed at very low exposure (WHO, 2023; CDC, 2024). Hexavalent chromium [Cr(VI)] and arsenic are classified as Group 1 human carcinogens, underscoring the importance of monitoring their presence in environmental media (IARC, 2012; IARC, 2023). Mercury—particularly as methylmercury—is neurotoxic and threatens fetal and early-life development (WHO, 2023; ATSDR, 2022).

This study provides a comprehensive review of empirical studies on heavy metal contamination in soils, drawing from both foundational sources and recent literature (2020–present). It integrates findings from diverse contamination sources—including municipal solid-waste dumpsites, industrial zones, urban centers, and agricultural areas—that contribute significantly to heavy metal accumulation.

The review emphasizes observed heavy metal concentrations, spatial distribution, and environmental factors influencing mobility, bioavailability, and persistence. It also underscores their ecological and human health risks, especially given their non-biodegradable nature and capacity for bioaccumulation and biomagnification (Nagajyoti et al., 2010; Bouhadi et al., 2021).

Globally—and particularly in developing regions such as Nigeria—studies consistently point to unmanaged waste disposal, industrial effluents, and contaminated agricultural practices as key drivers of soil contamination (Khan et al., 2010; Obiora et al., 2015; Adelekan & Abegunde, 2011). Evidence shows that contaminants frequently spread beyond immediate dumping areas, affecting broader ecosystems and posing serious public health risks (Alloway, 2013; Li et al., 2020; Nzediegwu et al., 2022).

In Ibadan, a rapidly expanding Nigerian metropolis where open dumping remains widespread, earlier research across dumpsites like Awotan, Lapite, and Ajakanga/Asunle has documented elevated trace and heavy metal levels in soils, groundwater, and edible plants (Adelekan & Abegunde, 2011; Olayiwola et al., 2017; Saheed et al., 2020). The very recent study by Adesanjo & Oloyede (2024) reported high concentrations of lead, iron, and nickel in surface and groundwater samples near the Ajakanga dumpsite, rendering many water sources unsuitable for consumption. Collectively, these findings affirm that unmanaged dumping remains a significant localized source of Pb, Cd, Ni, Cr, Hg, and other heavy metals in Ibadan (Adelekan & Abegunde, 2011; Adesanjo & Oloyede, 2024).

The Asunle dumpsite in Ibadan (often referred to in the literature alongside Ajakanga in Oluyole Local Government Area) sits within a landscape where rainfall, soil texture/structure, and waste composition can collectively influence metal mobility and retention. Recent site-specific work in the Ajakanga–Asunle environs has documented contamination signatures attributable to municipal wastes, including physicochemical and metal indicators in soils, supporting the hypothesis that waste management practices contribute to local geochemical anomalies.

Figure 1: Map of Asunle MSW landfill area

Description of the Study Area

The Asunle dumpsite (Fig. 1) is located in Ibadan, the capital of Oyo State, southwestern Nigeria, within Oluyole Local Government Area. Ibadan is among the largest cities in sub-Saharan Africa, with rapid urban expansion, high population density, and diverse socio-economic activities that generate substantial quantities of municipal solid waste daily. The Asunle dumpsite functions as one of the city's major open disposal sites, receiving mixed wastes from households, markets, industries, and commercial establishments.

Geographically, the dumpsite lies within the humid tropical climatic zone of Nigeria, with an annual rainfall ranging from 1,200 to 1,500 mm, concentrated between April and October, and a distinct dry season extending from November to March. Average annual temperatures vary between 25 °C and 29 °C, while relative humidity typically exceeds 70% during the wet months. These climatic conditions promote the generation of leachate and increase the likelihood of percolation of dissolved contaminants into surrounding soils and shallow groundwater.

Samples and Sampling Sites

Topsoil samples (0–15cm) were systematically collected from three main operational zones of the Asunle municipal solid waste dumpsite, with additional receptor locations situated along its periphery. A control site, located at a safe distance from potential contamination influence, was also included to provide a comparative baseline. Composite sampling was employed, with subsamples taken at multiple points within each zone to account for spatial variability.

Surface soils (0-15cm) were obtained using a stainless-steel auger, transferred into acid-washed polyethylene bags, sealed, and transported under cooled conditions to the laboratory. In the laboratory, the soils were air-dried at ambient temperature (25-28°C), homogenized, cleared of stones and plant residues, pulverized with an agate mortar, and passed through a 2 mm mesh sieve to obtain the fine fraction suitable for heavy metal analysis.

Analysis of Samples

This procedure describes the complete methodology for the determination of total concentrations of toxic heavy metals.

1. Sample Pre-treatment (Preparation)

Prior to digestion, the sieved soil samples were air-dried at room temperature to remove moisture without altering the chemical forms of the metals. The samples were subsequently oven-dried at 105 °C for 24 hours to achieve a constant weight. The 2mm dry fraction was retained for digestion, as it is the most reactive and has a higher affinity for trace metal binding.

2. Acid Digestion (U.S. EPA Method 3050B)

This digestion method was used to dissolve the total recoverable metal content from the soil matrix, directly addressing the reviewer's request for the quantification methodology:

Sample Weighing: Homogenized soil samples (5g) were accurately weighed into digestion flasks.

Acid Mixture: The samples were treated with 20mL of a ternary acid mixture consisting of Sulphuric acid (H_2SO_4), Perchloric acid ($HClO_4$), and Nitric acid (HNO_3) in the precise volume ratio of 1.5:2:3.

Heating: The mixture was heated on a hotplate under a fume hood until complete dissolution was achieved (the solution turned clear), which typically required 3.5 hours of continuous heating.

Final Step: After cooling, the digests were diluted to a fixed volume (20mL) with ultrapure water, centrifuged at 5000 rpm for 5 minutes, and the supernatant transferred into pre-cleaned polyethylene vials for instrumental analysis.

3. Instrumental Quantification by ICP-OES

The concentration of the target heavy metals in the prepared digest solutions was quantified using a Perkin Elmer Optima 8000 Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). Quantification was achieved by measuring the emitted light intensity at specific wavelengths for each element, against a calibration curve derived from Certified Reference Standard (CRS) solutions. The final results were calculated and expressed on a dry-weight basis (μg/kg).

Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) measures were rigorously applied throughout the analytical procedure. A **Standard Check Solution** prepared from the certified stock was analyzed after every tenth sample to verify instrument stability and calibration integrity. Results were accepted if the deviation from the true concentration was within ±10%; otherwise, the instrument was recalibrated. Analytical blanks and reagent blanks were included in each digestion batch to detect any background contamination. Spiked recoveries and duplicate analyses were also performed to assess accuracy and precision.

All glassware and sample containers were thoroughly acid-washed in 10% HNO□ and rinsed with ultrapure water before use. Only high-purity analytical-grade reagents were employed. The heavy metal concentrations in soils were expressed on a dry-weight basis (µg/kg). These procedures ensured accuracy, precision, and reproducibility of the ICP-OES measurements, providing confidence in the reliability of the reported heavy metal levels in soils from the Asunle dumpsite and its surrounding environment.

Results and Discussion

Figure 1: General view of the Asunle dumpsite showing the surrounding environment and waste accumulation pattern

The concentrations of Pb, As, Cd, Cr, Ni, and Hg in soils from the Asunle dumpsite are presented in Table 1. Overall, the detected levels were in the ppb (µg/kg) range, with dumpsite and receptor soils consistently exhibiting higher concentrations than the control site. This clearly demonstrates the influence of waste disposal activities on trace metal accumulation in the study area.

Table 1: Mean (± SD) of Toxic Heavy metal concentration in soil samples

Sample Location	Sample Identity	Pb(µg/kg)	As(µg/kg)	Cd(µg/kg)	Cr(µg/kg)	Ni(µg/kg)	Hg(µg/kg)
Zone A	Sample A	887.46 ± 24.20	1.90 ± 0.05	2.92 ± 0.08	576.01 ± 15.71	206.28 ± 5.63	0.75 ± 0.02
	Sample B	981.71 ± 18.02	2.10 ± 0.04	3.23 ± 0.06	637.19 ± 11.69	228.18 ± 4.19	0.83 ± 0.02
	Sample C	768.87 ± 25.17	1.65 ± 0.05	2.53 ± 0.08	499.04 ± 16.34	178.71 ± 5.85	0.65 ± 0.02
	Sample D	619.62 ± 4.71	1.33 ± 0.01	2.04 ± 0.02	402.17 ± 3.06	144.02 ± 1.10	0.52 ± 0.00
	Sample E	1125.55 ± 18.14	2.41 ± 0.04	3.70 ± 0.06	730.55 ± 11.78	261.62 ± 4.22	0.95 ± 0.02
	Sample F	686.30 ± 31.95	1.47 ± 0.07	2.26 ± 0.11	445.45 ± 20.74	159.52 ± 7.43	0.58 ± 0.03
Zone B	Sample A	1854.37 ± 27.40	3.97 ± 0.06	6.10 ± 0.09	1203.59 ± 17.79	431.01 ± 6.37	1.56 ± 0.02
	Sample B	840.86 ± 9.44	1.80 ± 0.02	2.77 ± 0.03	545.77 ± 6.13	195.44 ± 2.20	0.71 ± 0.01
	Sample C	1710.55 ± 52.40	3.66 ± 0.11	5.63 ± 0.17	1110.25 ± 34.01	397.59 ± 12.18	1.44 ± 0.04
	Sample D	1017.67 ± 37.53	2.18 ± 0.08	3.35 ± 0.12	660.52 ± 24.36	236.54 ± 8.72	0.86 ± 0.03
	Sample E	844.42 ± 27.27	1.81 ± 0.06	2.78 ± 0.09	548.08 ± 17.70	196.27 ± 6.34	0.71 ± 0.02
	Sample F	733.19 ± 14.88	1.57 ± 0.03	2.41 ± 0.05	475.88 ± 9.66	170.42 ± 3.46	0.62 ± 0.01
Zone C	Sample A	1002.06 ± 61.60	2.15 ± 0.13	3.30 ± 0.20	650.40 ± 39.98	232.91 ± 14.32	0.85 ± 0.05
	Sample B	769.72 ± 38.78	1.65 ± 0.08	2.53 ± 0.13	499.59 ± 25.17	178.91 ± 9.01	0.65 ± 0.03
	Sample C	1363.00 ± 28.91	2.92 ± 0.06	4.49 ± 0.10	884.67 ± 18.77	316.81 ± 6.72	1.15 ± 0.02
	Sample D	1014.41 ± 47.31	2.17 ± 0.10	3.34 ± 0.16	658.41 ± 30.70	235.78 ± 11.00	0.86 ± 0.04

	Sample E	657.31 ± 40.25	1.41 ± 0.09	2.16 ± 0.13	426.63 ± 26.12	152.78 ± 9.35	0.55 ± 0.03
	Sample F	897.87 ± 25.77	1.92 ± 0.06	2.96 ± 0.08	582.77 ± 16.73	208.69 ± 5.99	0.76 ± 0.02
Receptor Site	Sample A	2328.06 ± 15.08	4.98 ± 0.03	7.66 ± 0.05	1511.04 ± 9.79	541.12 ± 3.50	1.96 ± 0.01
	Sample B	1838.37 ± 14.07	3.94 ± 0.03	6.05 ± 0.05	1193.21 ± 9.13	427.30 ± 3.27	1.55 ± 0.01
	Sample C	1950.36 ± 16.88	4.18 ± 0.04	6.42 ± 0.06	1265.90 ± 10.96	453.33 ± 3.92	1.64 ± 0.01
Control Sample		609.62 ± 4.71	1.29 ± 0.02	2.01 ± 0.00	402.17 ± 1.03	142.02 ± 1.10	0.42 ± 0.00
Standard Check Solution (4.0ppm)		3.9969	3.9967	4.0000	3.9997	3.9997	4.0126
R^2		0.9997	0.9991	0.9994	0.9998	0.9996	0.9997
*Values are mean of triplicate analysis, SD = standard deviation							

Among the analyzed metals, Pb and Cr recorded the highest concentrations across the dumpsite zones, with values ranging from several hundred to over 1000 µg/kg. Arsenic and cadmium occurred at relatively lower levels, while nickel and mercury were present in moderate but detectable amounts. The general concentration trend across most metals followed the order: control less than dumpsite zones less than receptor sites, indicating outward migration of contaminants from the point source. The enrichment observed at the receptor site further suggests possible transport via leaching and surface runoff.

Spatial variability was also evident among the zones, reflecting the heterogeneous nature of solid waste deposition. Zone B, in particular, exhibited elevated Pb, Cr, and Ni levels, likely due to frequent disposal of batteries, paints, metallic scraps, and other e-waste. Scavenging activities at the dumpsite, such as dismantling of materials and informal recycling, may have further contributed to uneven distribution, creating localized contamination hotspots.

Below most international soil quality guideline limits, their consistent elevation above background (control) values confirms anthropogenic inputs. The observed enrichment, particularly of Pb and Cr, highlights potential long-term risks of soil deterioration and bioaccumulation if unchecked.

Ecological Risk Assessment

To assess the potential ecological impacts of heavy metal contamination at the Asunle dumpsite and its surroundings, we employed the methods of Hakanson (1980), involving the calculation of the Contamination Factor (C_f), the Ecological Risk Factor (E_r) and the Ecological Risk Index(RI) These parameters help quantify the degree of environmental risk posed by individual metals and the cumulative risk across multiple contaminants.

Ecological Risk Assessment Methodology

The assessment utilized the following background concentrations ($C_{background}$), defined as the lowest measured concentration of each metal across all sampling zones:

The Background values are: Pb: 609.6236 ug/kg, As: 1.2998 ug/kg, Cd: 2.0056 ug/kg, Cr: 394.8908 ug/kg, Ni: 142.0206 ug/kg, Hg: 0.5112 ug/kg

We used the following formulas:

1. **Contamination Factor (C_f)** = $C_{sample} / C_{background}$

   Where: C_{sample} - concentration of metal in sample, $C_{background}$ - control sample

2. **Ecological Risk Factor (E_r)**: The E_r integrates the degree of contamination with the inherent toxicity of the element, using the Toxic Response Factor (T_r).

   $E_r = C_f \times T_r$

   The T_r values used are as follows: Pb: 5, Cd: 30, Cr: 2, Ni: 5, As: 10, Hg: 40

3. Risk Index (RI):

   $RI = \sum Eri = E_{rPb} + E_{rZn} + E_{rCd} + E_{rCr} + E_{rNi} + E_{rHg}$

   According to Hakanson's classification:

   RI Less than 50 = Low risk, 50 Less than or equal to RI Less than 150 = Moderate risk, 150 Less than or equal to RI Less than 300 = Considerable risk

The contamination factors (C_f) exhibited clear spatial variations, indicating distinct patterns of heavy metal enrichment across dumpsite zones and receptor soils. Most C_f values exceeded 1, signifying anthropogenic inputs beyond natural background levels. Moderate contamination (C_f = 1–3) dominated the majority of samples, while the highest C_f values (≈3–4) occurred at the receptor site, reflecting pollutant migration through leaching and surface runoff. Zone B also recorded relatively high C_f values, especially for Pb, Cd, and Cr, consistent with the intensive disposal of e-waste, spent batteries, and metallic scraps.

Table 2: Full Ecological Risk Assessment of Toxic Heavy Metals (µg/kg)

Sample ID	**Pb_Cf**	**As_Cf**	**Cd_Cf**	**Ni_Cf**	**Cr_Cf**	**Hg_Cf**	**PI**	**Pb_Er**	**As_Er**	**Cd_Er**	**Ni_Er**	**Cr_Er**	**Hg_Er**	**RI**
Sample A-A	1.46	1.46	1.46	1.45	1.46	1.46	1.46	7.3	14.6	43.8	7.25	2.92	58.4	134.27
Sample A-B	1.61	1.62	1.61	1.61	1.61	1.62	1.61	8.05	16.2	48.3	8.05	3.22	64.8	148.62
Sample A-C	1.26	1.27	1.26	1.26	1.26	1.27	1.26	6.3	12.7	37.8	6.3	2.52	50.8	116.42
Sample A-D	1.02	1.02	1.02	1.01	1.02	1.02	1.02	5.1	10.2	30.6	5.05	2.04	40.8	93.79
Sample A-E	1.85	1.85	1.85	1.84	1.85	1.86	1.85	9.25	18.5	55.5	9.2	3.7	74.4	170.55
Sample A-F	1.13	1.13	1.13	1.12	1.13	1.13	1.13	5.65	11.3	33.9	5.6	2.26	45.2	103.91
Sample B-A	3.04	3.05	3.04	3.03	3.05	3.06	3.05	15.2	30.5	91.2	15.15	6.1	122.4	280.55
Sample B-B	1.38	1.38	1.38	1.38	1.38	1.39	1.38	6.9	13.8	41.4	6.9	2.76	55.6	127.36
Sample B-C	2.81	2.82	2.81	2.80	2.81	2.82	2.81	14.05	28.2	84.3	14	5.62	112.8	258.97
Sample B-D	1.67	1.68	1.67	1.67	1.67	1.68	1.67	8.35	16.8	50.1	8.35	3.34	67.2	154.14
Sample B-E	1.39	1.39	1.39	1.38	1.39	1.39	1.39	6.95	13.9	41.7	6.9	2.78	55.6	127.83
Sample B-F	1.20	1.21	1.20	1.20	1.21	1.21	1.21	6	12.1	36	6	2.42	48.4	110.92
Sample C-A	1.64	1.65	1.64	1.64	1.65	1.65	1.65	8.2	16.5	49.2	8.2	3.3	66	151.4
Sample C-B	1.26	1.27	1.26	1.26	1.27	1.27	1.27	6.3	12.7	37.8	6.3	2.54	50.8	116.44
Sample C-C	2.24	2.24	2.24	2.23	2.24	2.25	2.24	11.2	22.4	67.2	11.15	4.48	90	206.43
Sample C-D	1.66	1.67	1.66	1.66	1.67	1.67	1.67	8.3	16.7	49.8	8.3	3.34	66.8	153.24
Sample C-E	1.08	1.08	1.08	1.08	1.08	1.08	1.08	5.4	10.8	32.4	5.4	2.16	43.2	99.36
Sample C-F	1.47	1.48	1.47	1.47	1.48	1.48	1.48	7.35	14.8	44.1	7.35	2.96	59.2	135.76

Receptor Site-A	3.82	3.83	3.82	3.81	3.83	3.84	3.83	19.1	38.3	114.6	19.05	7.66	153.6	352.31
Receptor Site-B	3.02	3.03	3.02	3.01	3.02	3.03	3.02	15.1	30.3	90.6	15.05	6.04	121.2	278.29
Receptor Site-C	3.20	3.21	3.20	3.19	3.21	3.22	3.21	16	32.1	96	15.95	6.42	128.8	295.27

The pollution index (PI), integrating the collective contamination of all metals, further supported this trend. PI values increased progressively from the dumpsite core (~1.0) to the receptor soils (~4.0), highlighting the influence of continuous waste deposition and informal scavenging activities that enhance contaminant redistribution and create localized hotspots.

Ecological Risk

The ecological risk factor (Er) identified Cd as the most critical metal, showing the highest individual ecological risk due to its large toxic response factor. Hg also contributed significantly, particularly at the receptor site, despite its moderate Cf values. Pb and Cr displayed lower Er values but contributed notably to the overall risk due to their elevated concentrations.

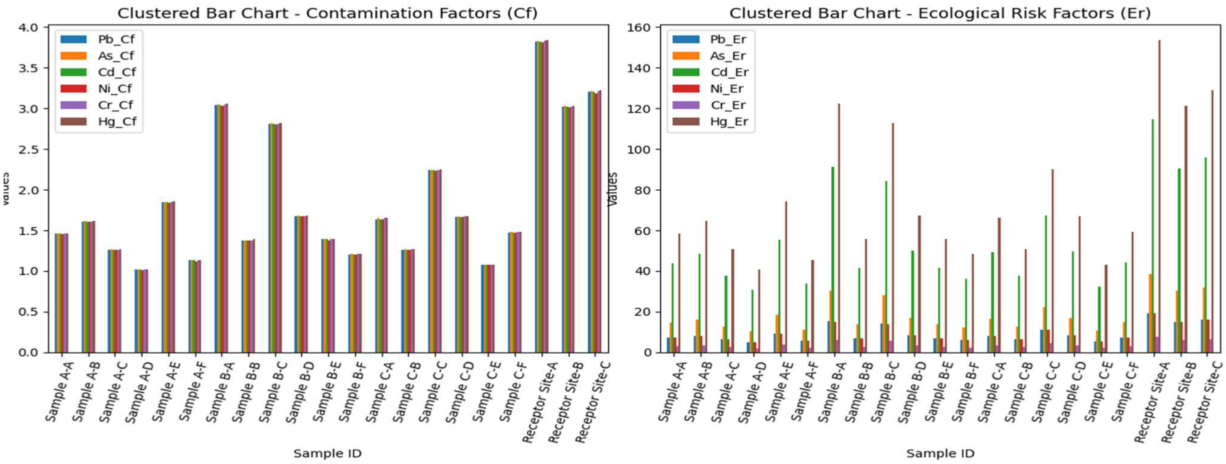

Figure 2: Clustered bar charts showing (a) Contamination Factors (Cf) and (b) Ecological Risk Factors (Er) of Pb, As, Cd, Ni, Cr, and Hg across Asunle dumpsite samples and receptor sites.

The potential ecological risk index (RI) ranged from ~90 in less contaminated soils to >350 at the receptor site. According to Hakanson's classification, dumpsite soils fall within the moderate–considerable risk range, while receptor soils approach very high risk. This confirms that contamination is not confined to the dumpsite but extends to surrounding areas, posing ecological and potential public health concerns.

Overall, the results indicate that:

- Cd and Hg present the highest ecological risks.
- Pb and Cr dominate the contamination load (high C_f and PI).
- Receptor soils exhibit the greatest RI, confirming outward migration of pollutants.
- Scavenging and informal recycling contribute significantly to contaminant redistribution and spatial heterogeneity.

Index of Geoaccumulation(Igeo) of Selected Toxic Heavy Metals

The geoaccumulation index (Igeo), originally introduced by Müller (1969), is widely used to assess the degree of heavy metal contamination in soils and sediments. It compares measured concentrations with background values while accounting for natural variability. The Igeo is calculated as:

$$\text{Igeo} = \log_2\left(\frac{C_n}{1.5 \times B_n}\right)$$

Where:

- C_n is the measured concentration of the metal in the sample,
- B_n is the geochemical background value (lowest observed value across all samples),
- 1.5 is a constant to account for natural variations in background data due to lithogenic effects.

Müller's (1969) classification scale for Igeo is as follows:

Class	Igeo Range	Pollution Description
0	Less than or equal to 0	Unpolluted
1	0–1	Unpolluted to moderately polluted
2	1–2	Moderately polluted
3	2–3	Moderately to heavily polluted
4	3–4	Heavily polluted
5	4–5	Heavily to extremely polluted
6	Greater than 5	Extremely polluted

The geoaccumulation index (Igeo) values obtained for Pb, As, Cd, Ni, Cr, and Hg in Batch 1 are presented in **Table 3**. The results provide a clear picture of the contamination status of the studied heavy metals across the different sampling zones and the receptor sites.

Table 3: Calculated Igeo values for Pb, As Cd in Batch 1 samples across all zones, including receptor site

Sample Location	Igeo_Pb	Igeo_As	Igeo_Cd	Igeo_Ni	Igeo_Cr	Igeo_Hg
Zone A-A	-0.043	-0.037	-0.042	-0.046	-0.067	-0.034
Zone A-B	0.102	0.108	0.103	0.099	0.079	0.110
Zone A-C	-0.250	-0.244	-0.249	-0.253	-0.274	-0.241
Zone A-D	-0.561	-0.556	-0.561	-0.565	-0.585	-0.553
Zone A-E	0.300	0.306	0.300	0.296	0.276	0.308
Zone A-F	-0.414	-0.408	-0.413	-0.417	-0.438	-0.406
Zone B-A	1.020	1.026	1.021	1.017	0.996	1.028
Zone B-B	0.274	0.271	0.272	0.271	0.237	-0.112
Zone B-C	0.904	0.909	0.904	0.900	0.880	0.912
Zone B-D	0.154	0.160	0.155	0.151	0.131	0.162
Zone B-E	-0.115	-0.109	-0.114	-0.118	-0.138	-0.107
Zone B-F	-0.319	-0.313	-0.318	-0.322	-0.342	-0.311
Zone C-A	0.132	0.138	0.133	0.129	0.109	0.140
Zone C-B	-0.249	-0.243	-0.248	-0.252	-0.272	-0.241
Zone C-C	0.576	0.582	0.577	0.573	0.552	0.584
Zone C-D	0.150	0.156	0.150	0.146	0.126	0.158
Zone C-E	-0.476	-0.470	-0.476	-0.480	-0.500	-0.468
Zone C-F	-0.026	-0.020	-0.026	-0.030	-0.050	-0.018
Receptor-A	1.348	1.354	1.349	1.345	1.325	1.356
Receptor-B	1.007	1.013	1.008	1.004	0.984	-0.240
Receptor-C	1.093	1.099	1.094	1.089	1.069	-0.034

As shown in Table 3, the Igeo values exhibit varying degrees of contamination across the zones. For Pb, As, Cd, Ni, and Cr, values range from approximately –0.56 to +1.35, spanning the unpolluted to moderately polluted categories according to Müller's classification. Zone A generally shows low or slightly negative Igeo values, indicating minimal contamination and near-background levels for most metals, except mercury (Hg), which exhibits extremely high values (greater than 9.3), signifying severe enrichment.

Zones B and C display a clear increase in contamination intensity, with several positive Igeo values (up to +1.02 and +0.58 respectively) for Pb, As, Cd, Ni, and Cr. These results suggest localized to moderate anthropogenic input, likely from waste accumulation, metal scraps, and leachates typical of dumpsite activities. Mercury remains consistently elevated across all sampling points, confirming its mobility and persistence within the dumpsite environment.

At the receptor sites, Igeo values are highest for all the studied metals, with Pb, As, Cd, Ni, and Cr exceeding +1.0, corresponding to the moderately polluted class.

Overall, the Igeo distribution pattern reveals that while the core zones (especially Zone A) remain relatively unpolluted for most metals, Zones B, C, and the receptor areas exhibit notable enrichment—particularly of mercury—underscoring ongoing pollutant migration and potential long-term ecological risk.

Conclusion

The present study assessed the concentrations of toxic heavy metals (As, Pb, Cd, Ni, and Cr) in soil samples collected from the Asunle dumpsite in Ibadan using ICP-OES. The findings revealed elevated levels of these metals compared to natural background concentrations, with some exceeding internationally recognized soil quality guidelines. The enrichment observed suggests that indiscriminate waste disposal at the site is contributing to the accumulation and possible migration of toxic elements into surrounding soils. Such contamination poses potential ecological and human health risks, particularly to communities engaging in urban agriculture or other activities around the dumpsite.

Recommendations

Based on these findings, it is recommended that:

1. **Regular monitoring** of heavy metal concentrations be instituted to track changes in contamination levels and assess potential risks over time.
2. **Site management strategies** such as controlled waste disposal, segregation of hazardous wastes, and leachate control be enforced to minimize further accumulation of toxic metals.
3. **Remediation measures** including phytoremediation or soil amendments should be explored to reduce the bioavailability of heavy metals within the site.
4. **Public health awareness campaigns** should be introduced to inform residents and farmers around the dumpsite about the risks of exposure through soil contact, dust inhalation, and food chain transfer.
5. **Policy and enforcement** efforts must be strengthened to regulate indiscriminate dumping and promote sustainable waste management practices in Ibadan.

In summary, while the Asunle dumpsite continues to serve as a major waste disposal point, its role as a potential environmental hotspot for toxic metals cannot be overlooked. Addressing this challenge requires an integrated approach that combines scientific monitoring, effective waste management, remediation interventions, and community engagement.

References

Adesanjo, A. S., & Oloyede, O. A. (2024). Heavy metal concentration assessment of surface and groundwater in the vicinity of Ajakanga dumpsite, Oluyole, Ibadan, southwestern Nigeria. *African Journal of Environment and Natural Science Research*, *7*(2), 148–164.

Adesewa, A., & Morenikeji, O. (2017). Helminths and heavy metals in soils from a dumpsite in Ibadan city, Nigeria. *Journal of Preventive Medicine and Hygiene*, *58*(4), E328–E333. https://doi.org/10.15167/2421-4248/jpmh2017.58.4.608

Adelekan, B. A., & Abegunde, K. D. (2011). Heavy metal contamination of soil and groundwater at automobile mechanic villages in Ibadan, Nigeria. *International Journal of the Physical Sciences*, *6*(5), 1045–1058.

Agency for Toxic Substances and Disease Registry (ATSDR). (2012). *Toxicological profile for cadmium*. U.S. Department of Health and Human Services.

Agency for Toxic Substances and Disease Registry (ATSDR). (2022). *Toxicological profile for mercury*. U.S. Department of Health and Human Services.

Alloway, B. J. (2013). *Heavy metals in soils: Trace metals and metalloids in soils and their bioavailability* (3rd ed.). Springer.

Bouhadi, M., el Kouali, M., Talbi, M., & Tarik, A. (2021). Phytoremediation Review: Bioavailability of heavy metals and the role of bioaccumulative plants in the remediation of contaminated soils. *Journal of Applied Sciences and Advanced Business*, *3*, 40–47. https://doi.org/10.48402/IMIST.PRSM/jasab-v3i1.28238

Centers for Disease Control and Prevention (CDC). (2024). *Blood lead reference value*. CDC.

Centers for Disease Control and Prevention (CDC). (2024). *Preventing childhood lead poisoning*. CDC.

International Agency for Research on Cancer (IARC). (2012). *Arsenic, metals, fibres and dusts* (Vol. 100C). IARC monographs on the evaluation of carcinogenic risks to humans. IARC.

International Agency for Research on Cancer (IARC). (2023). *List of classifications by cancer site*. https://monographs.iarc.who.int/

Kabata-Pendias, A. (2011). *Trace elements in soils and plants* (4th ed.). CRC Press.

Khan, S., Rehman, S., Khan, A., Khan, M., & Shah, M. (2010). Soil and Vegetables Enrichment with Heavy Metals from Geological Sources in Gilgit, Northern Pakistan. *Ecotoxicology and Environmental Safety*, *73*(7), 1820–1827. https://doi.org/10.1016/j.ecoenv.2010.08.016

Li, Z., Ma, Z., van der Kuijp, T. J., Yuan, Z., & Huang, L. (2014). A review of soil heavy metal pollution from mines in China: Pollution and health risk assessment. *Science of the Total Environment*, *626*, 468–489.

Nagajyoti, P. C., Lee, K. D., & Sreekanth, T. V. M. (2010). Heavy metals, occurrence and toxicity for plants: A review. *Environmental Chemistry Letters*, *8*(3), 199–216.

Nzediegwu, C., Chang, S. X., & Ekwealor, I. A. (2022). Soil contamination by heavy metals and health risk assessment around municipal dumpsites in sub-Saharan Africa. *Environmental Science and Pollution Research*, *29*(3), 3564–3579.

Obiora, S., Chukwu, A., & Davies, T. (2015). Heavy metals and health risk assessment of arable soils and food crops around Pb-Zn mining localities in Enyigba, southeastern Nigeria. *Journal of African Earth Sciences*, *116*, Article 103757. https://doi.org/10.1016/j.jafrearsci.2015.12.025

Olagunju, T., Olagunju, O., Akawu, I., & Ugokwe, C. (2020). *Quantification and Risk Assessment of Heavy Metals in Groundwater and Soil of Residential Areas around Awotan Landfill, Ibadan, Southwest-Nigeria*. [Unpublished manuscript].

Olayiwola, H. A., Abudulawal, L., Adewuyi, K. G., & Azeez, M. O. (2017). Heavy metal contents in soil and plants at dumpsites: A case study of Awotan and Ajakanga dumpsite, Ibadan, Oyo State, Nigeria. *Journal of Environmental and Earth Science*, *7*(1), 11–24.

Saheed, I. O., Azeez, S. O., Jimoh, A. A., Obaro, V. A., & Adepoju, S. A. (2020). Assessment of some heavy metals' concentrations in soil and groundwater around refuse dumpsites in Ibadan metropolis, Nigeria. *Nigerian Journal of Technology*, *39*(1), 301–305.

U.S. Environmental Protection Agency (U.S. EPA). (2025). *Regional screening levels (RSLs)—Generic tables*. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

World Health Organization (WHO). (2023). *Lead poisoning and health: Key facts*. https://www.who.int/news-room/fact-sheets

World Health Organization (WHO). (2023). *Mercury and health*. https://www.who.int/news-room/fact-sheets

World Health Organization (WHO). (2024). *Lead poisoning and health* (Fact sheet).